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Assessment of MJO prediction in operational models: NCEP CFSv2 and ECMWF VarEPS

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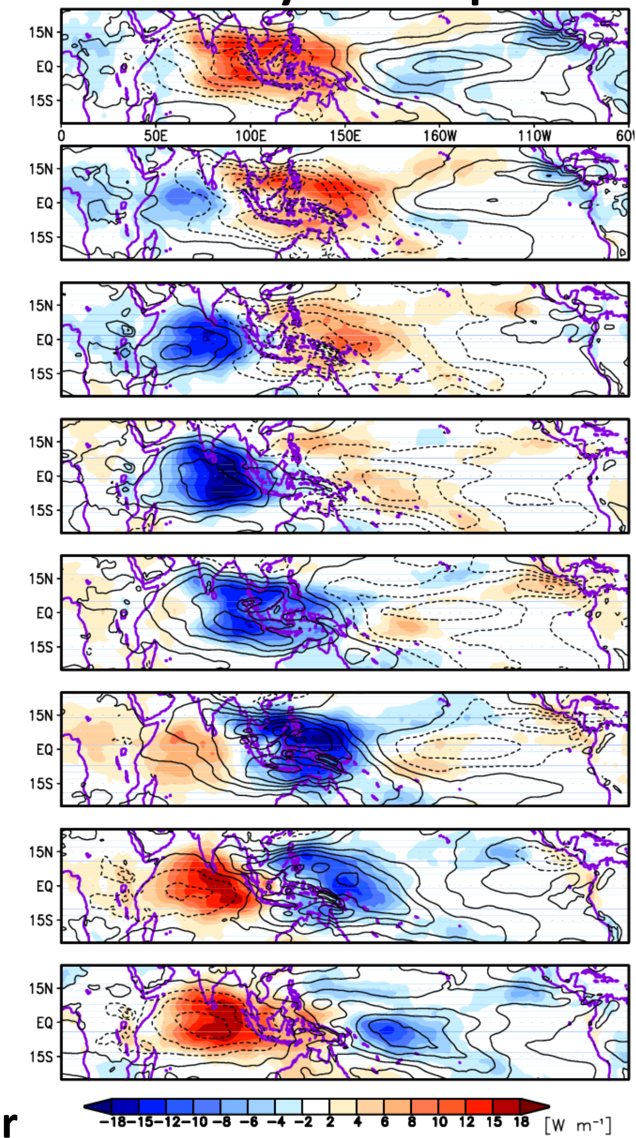
Outline

- Prediction skill
  - Dependency on initial/target amplitude
  - Dependency on initial/target phase
- Amplitude change
- Propagation speed
- Summary

Background

MJO life-cycle composite



OLR: shading
U850: contour

What is MJO ?

- Discovered by **Madden and Julian** (1971).
- **MJO** is an tropical **intraseasonal** oscillation of enhanced and suppressed convection with a period of 20-70 days.

Evolution

- MJO tends to **develop in the Indian Ocean** and **propagate eastward**

Impacts

- Monsoon, ENSO, Tropical cyclone, Aerosol, Winter Snowstorms in the US, …

Background

Model	Corr=0.5	Initialization	Period	reference
CFSv2	~20 days	Every day	1999-2010	Wang et al. (2013)
CFSv1	**~15 days**	15 different dates per month	1982-2004	Seo et al. (2009)
GloSea4 (HadGEM3)	**~17 days**	Once per week	1989-2002	Arribas et al. (2011)
POAMA	**~20 days**	Once per month	1980-2006	Rashid et al. (2010)
ECMWF Cy32r3	**~23 days**	Once per month	1989-2008	Vitart et al. (2010)
SNU CGCM	**~ 18 days**	Every 5 day	1980-2007	Kang and Kim (2010)
CCCma GCM3	**~ 6 days**	Once per month	1969-2003	Lin et al. (2008)

The ECMWF VarEPS-monthly forecasting system

- A 51-member ensemble is integrated for 32 days twice a week (Mondays and Thursdays at 00Z)
- Atmospheric component: IFS with the latest operational cycle and with a T639L62 resolution till day 10 and T319L62 after day 10.
- Persisted SST anomalies till day 10 and ocean-atmosphere coupling from day 10 till day 32.
- Oceanic component: HOPE (from Max Plank Institute) with a zonal resolution of 1.4 degrees and 29 vertical levels
- Coupling: OASIS (CERFACS). Coupling every 3 hours.
- **5-member ensemble integrated at the same day and same month as the real-time time forecast over the past 18 years with initial conditions from ERA Interim.**

F. Vitart (MJO workshop, June 2013)

Data

- **Hindcasts of the coupled climate models**

	NCEP CFSv2	ECMWF VarEPS
Resolution	T126 L64	T319 L62
Ensembles	4	5
Forecast days	45	32
Initialization	Every day CFSR	Twice per week ERA interim
Period	2000-2009, 3650 cases	1993~2009, 1836 cases

Data

- **Variables**

  OLR, U850, U200

- **Observations**

  OLR (NOAA/AVHRR), U850, U200 (ERAI)

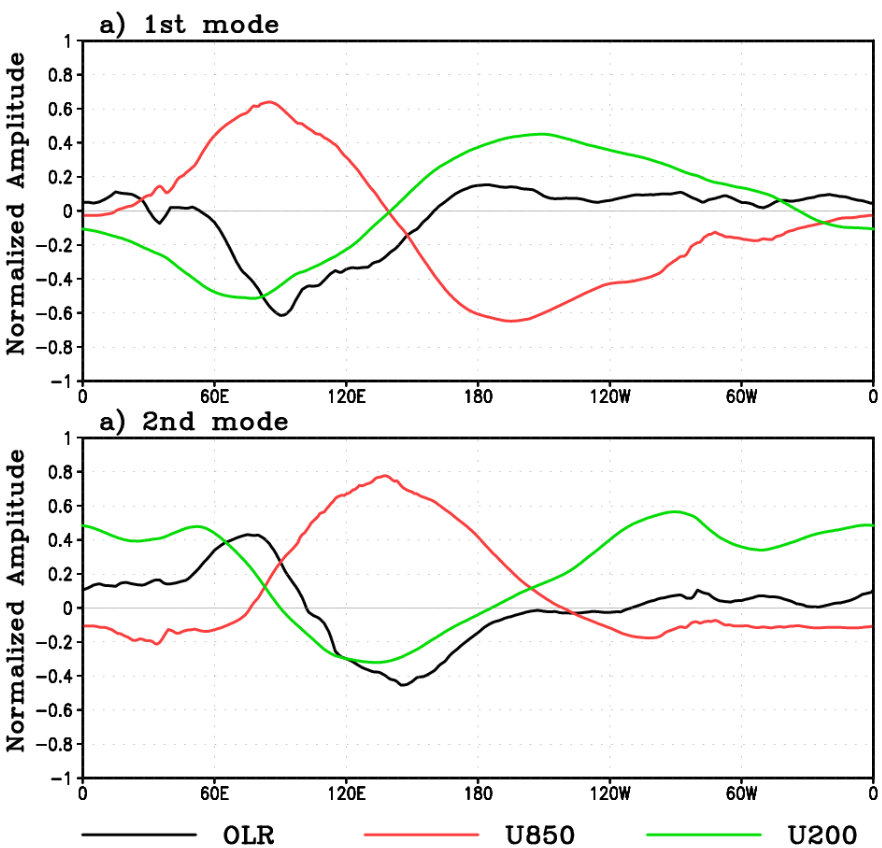
  1981-2010

- **RMM index (WH04)**

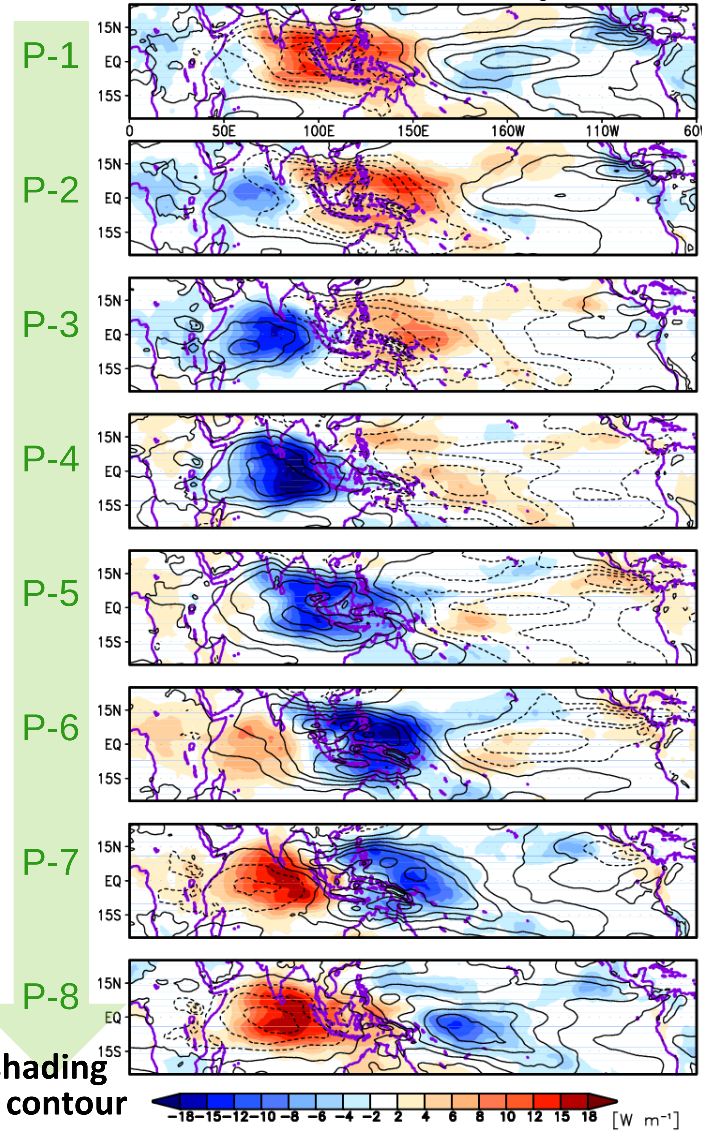
  Forecasts are projected into combined EOFs

Definition of MJO

Eigenvector of 1st and 2nd EOF



MJO life-cycle composite



OLR: shading
U850: contour

Real-time Multivariate MJO (RMM) index, Wheeler and Hendon (2004)

Methodology

- **Bivariate ACC**

$$\mathrm{COR}(\tau) = \frac{\sum_{t=1}^{N}[a_1(t)b_1(t,\tau) + a_2(t)b_2(t,\tau)]}{\sqrt{\sum_{i=1}^{N}[a_1^2(t) + a_2^2(t)]}\sqrt{\sum_{i=1}^{N}[b_1^2(t,\tau) + b_2^2(t,\tau)]}}$$

Gottschalck et al. (2010)
Lin et al. (2008)

- **Amplitude**

AMP (t) $= \sqrt{\boldsymbol{a1(t)^2 + a2(t)^2}}$

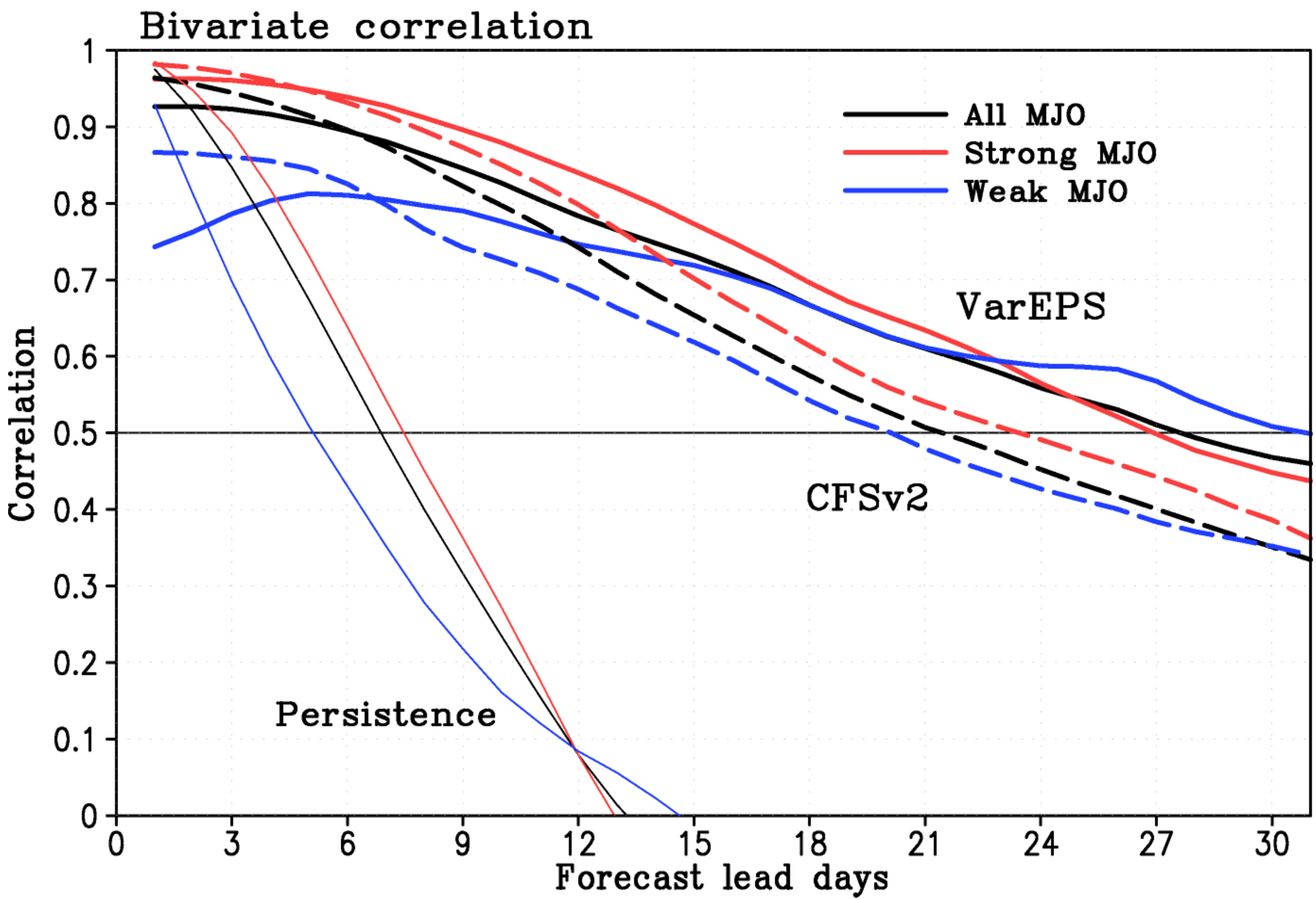
Strong MJO > 1.5 (~32%)
Weak/no MJO < 1.0 (~32%)

- **Phase speed**

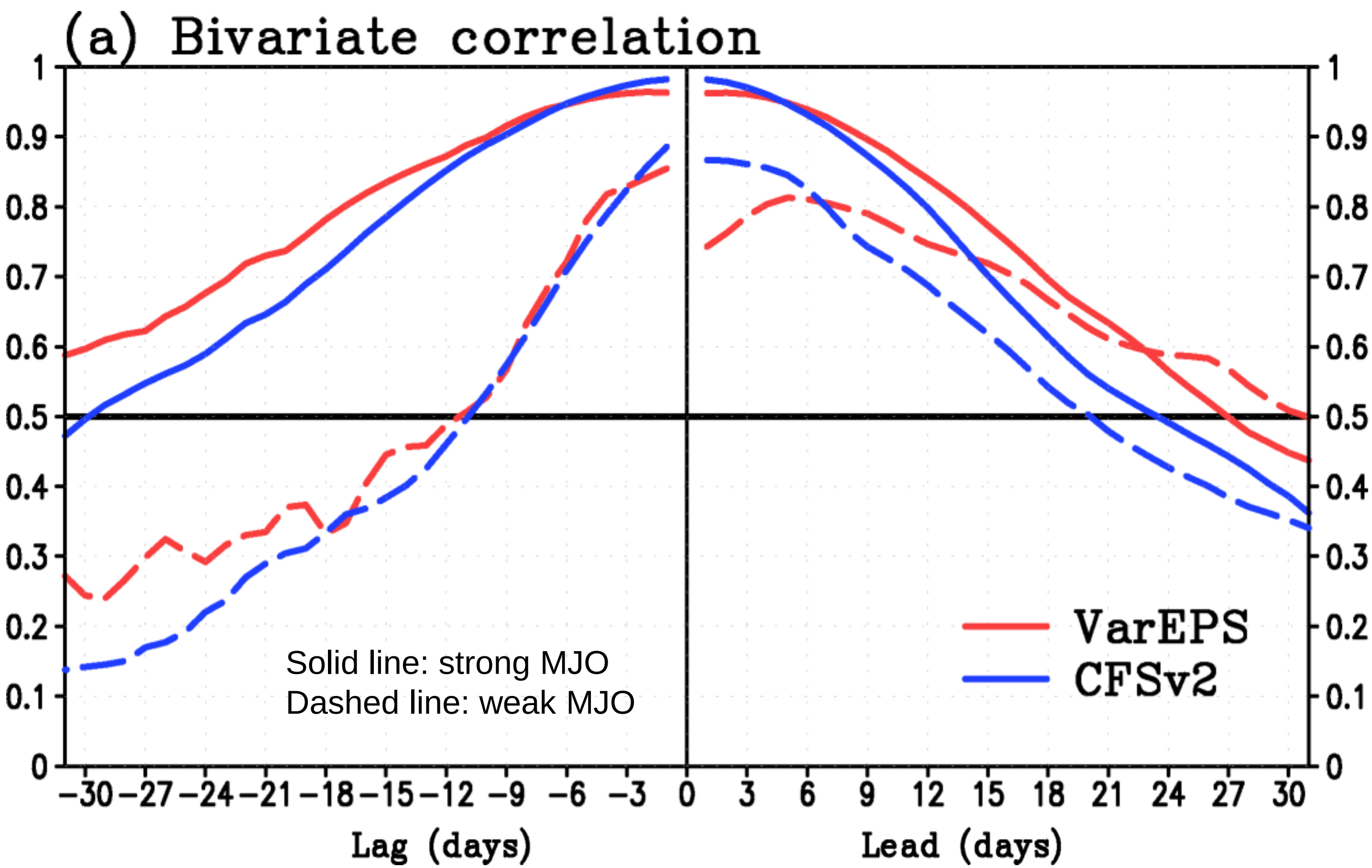
ANG (t) = $\tan^{-1}$ [a2(t)/a1(t)]

- a1(t) and a2(t) are the verification RMM1 and RMM2 at time t
- b1(t,τ) and b2(t,τ) are the respective forecasts for time t for a lead time of τ days
- N is the number of forecasts.

Skill dependency on initial MJO amplitude



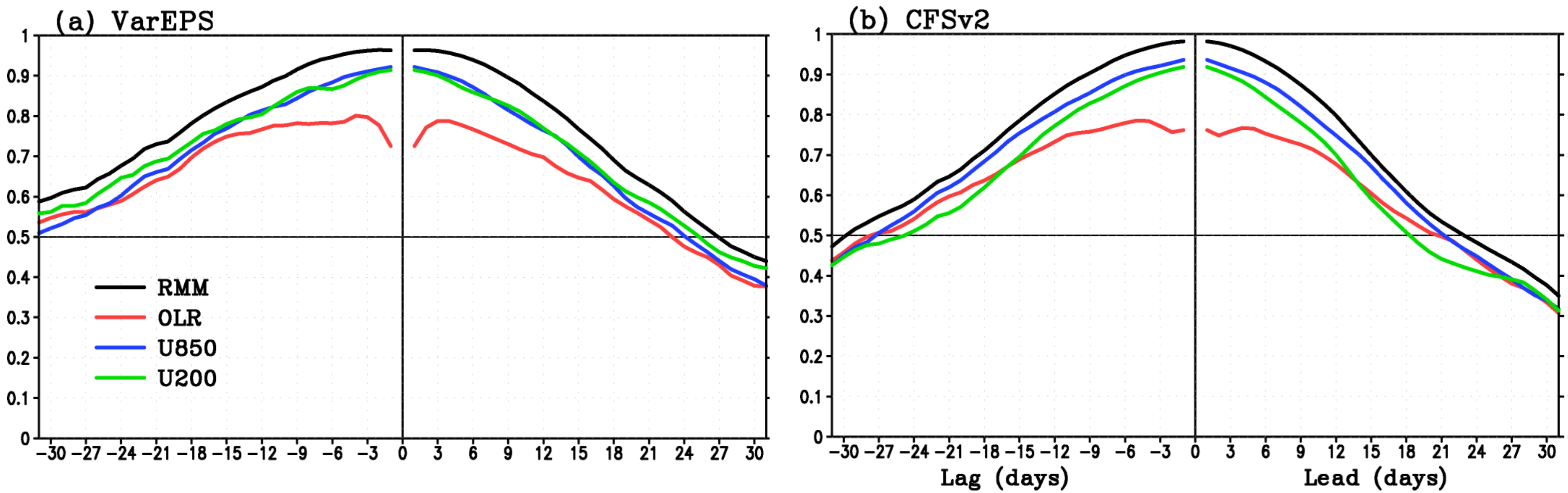
Skill dependency on initial/target MJO amplitude



- The initially strong MJO clearly possesses a greater predictive skill compared to the initially weak MJO in both the hindcasts.
- When forecast is targeting days with strong MJO signal, both systems are able to make useful prediction about 30 days in advance.

The source of RMM prediction skill

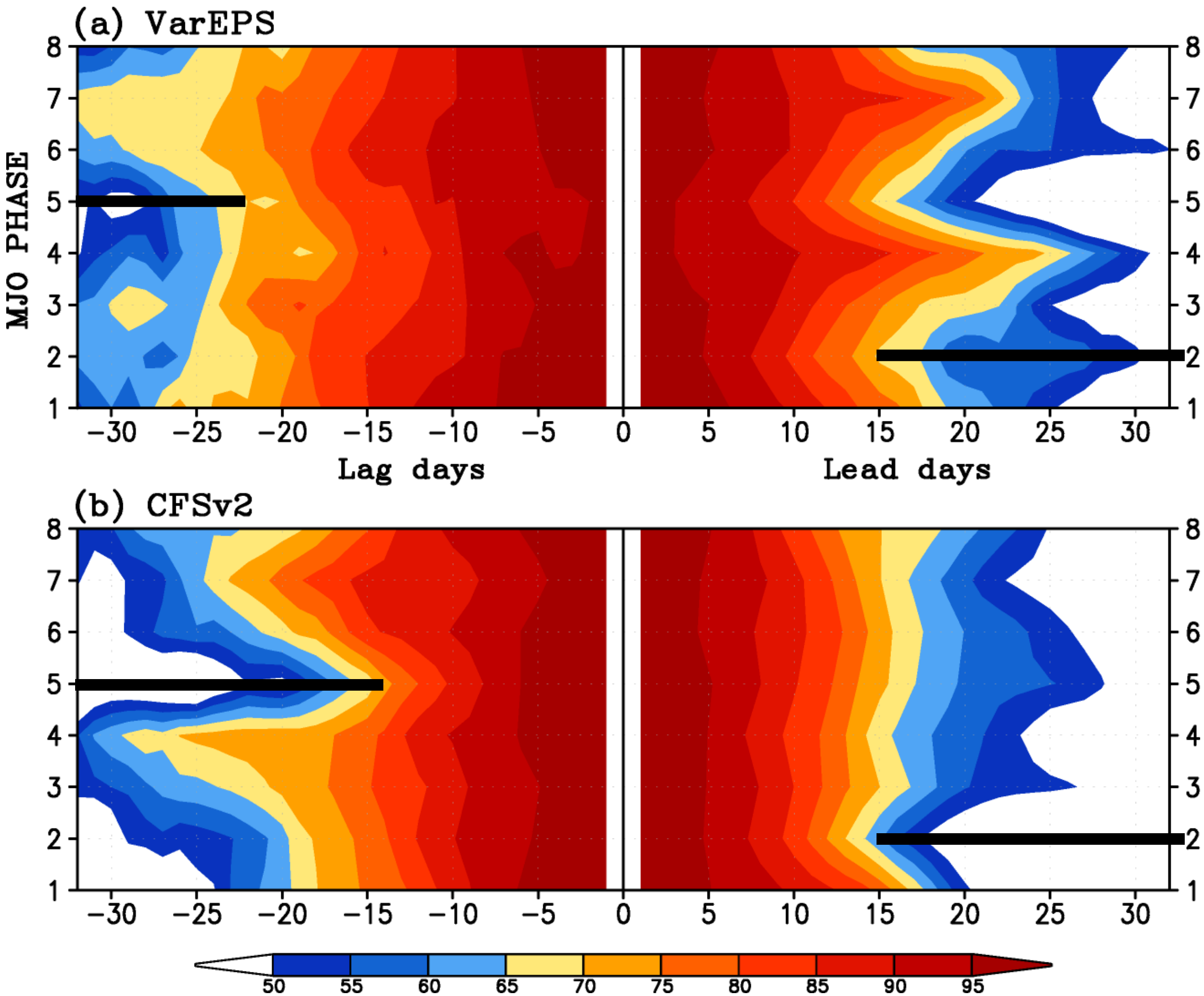
Bivariate correlation

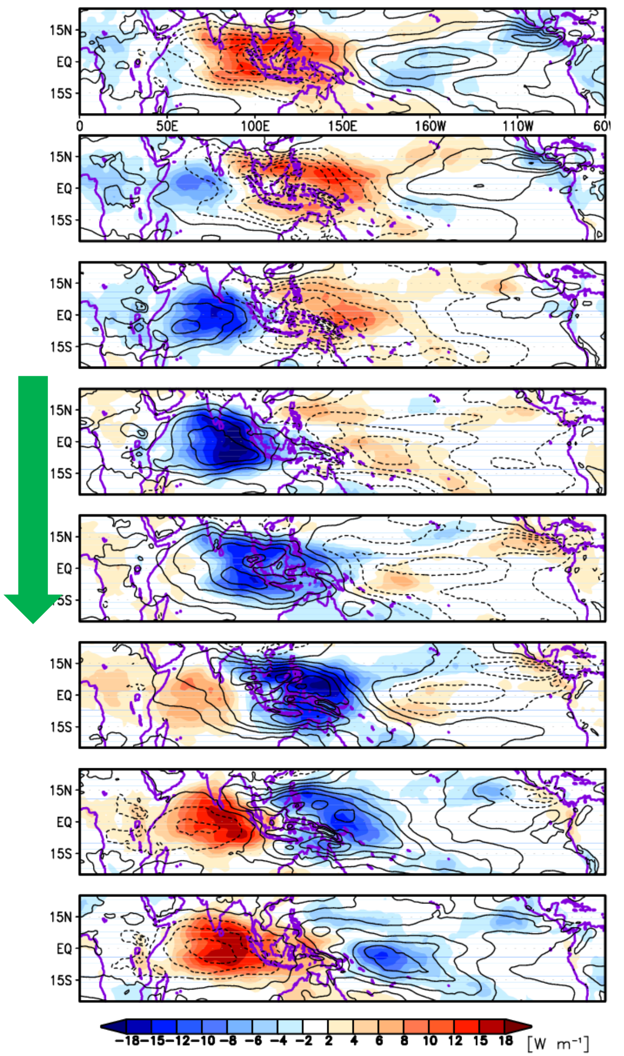


- Figures show the prediction skill decomposed by different variables used in RMM index
- The forecast skill of a strong MJO is dominated by the skill of circulation-associated anomalies rather than the convective anomalies
- Better representation of convection and its interaction with large-scale circulation in dynamical models is crucial to extend the MJO prediction skill

Skill dependency on MJO phases

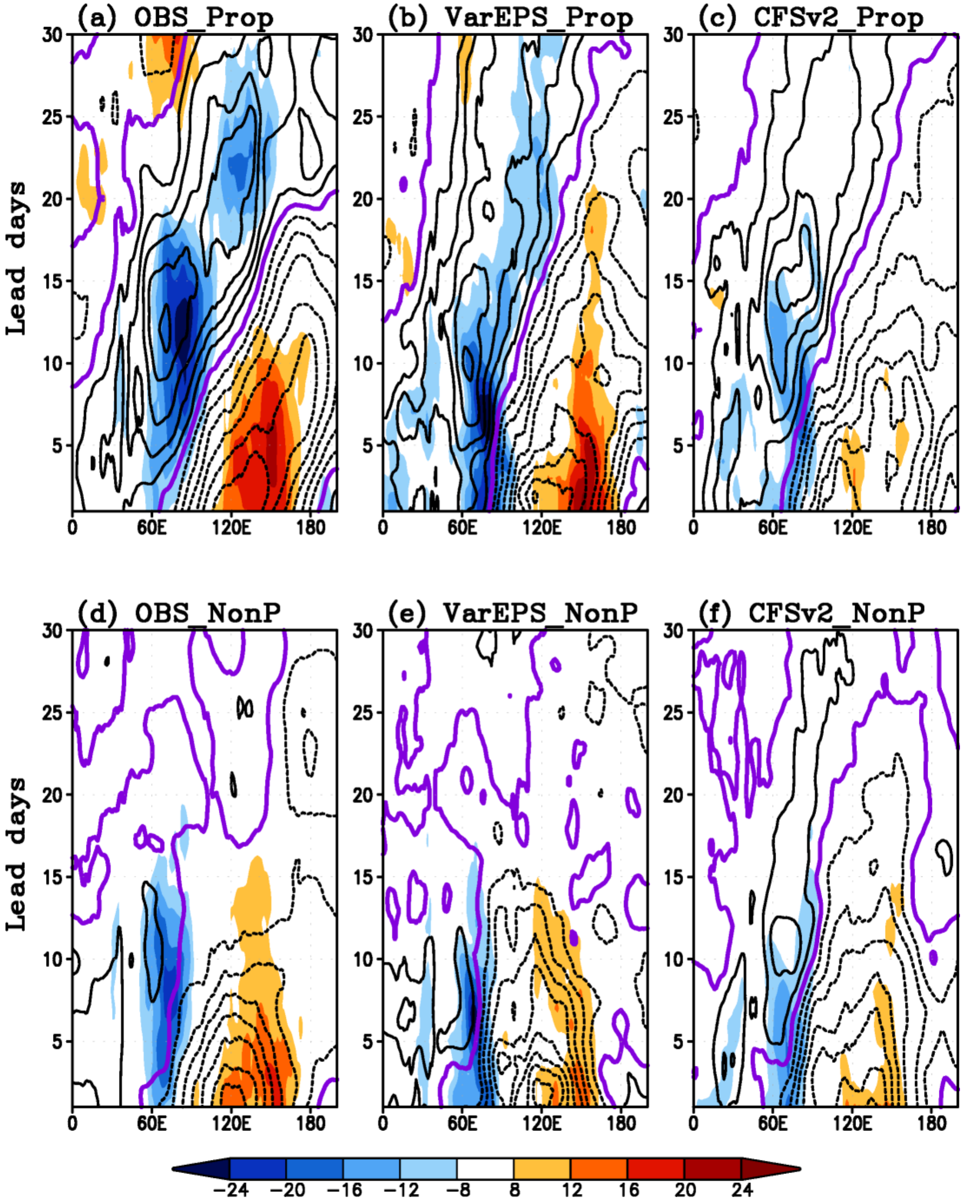
Bivariate correlation





“Maritime Continent MJO Predictability Barrier”

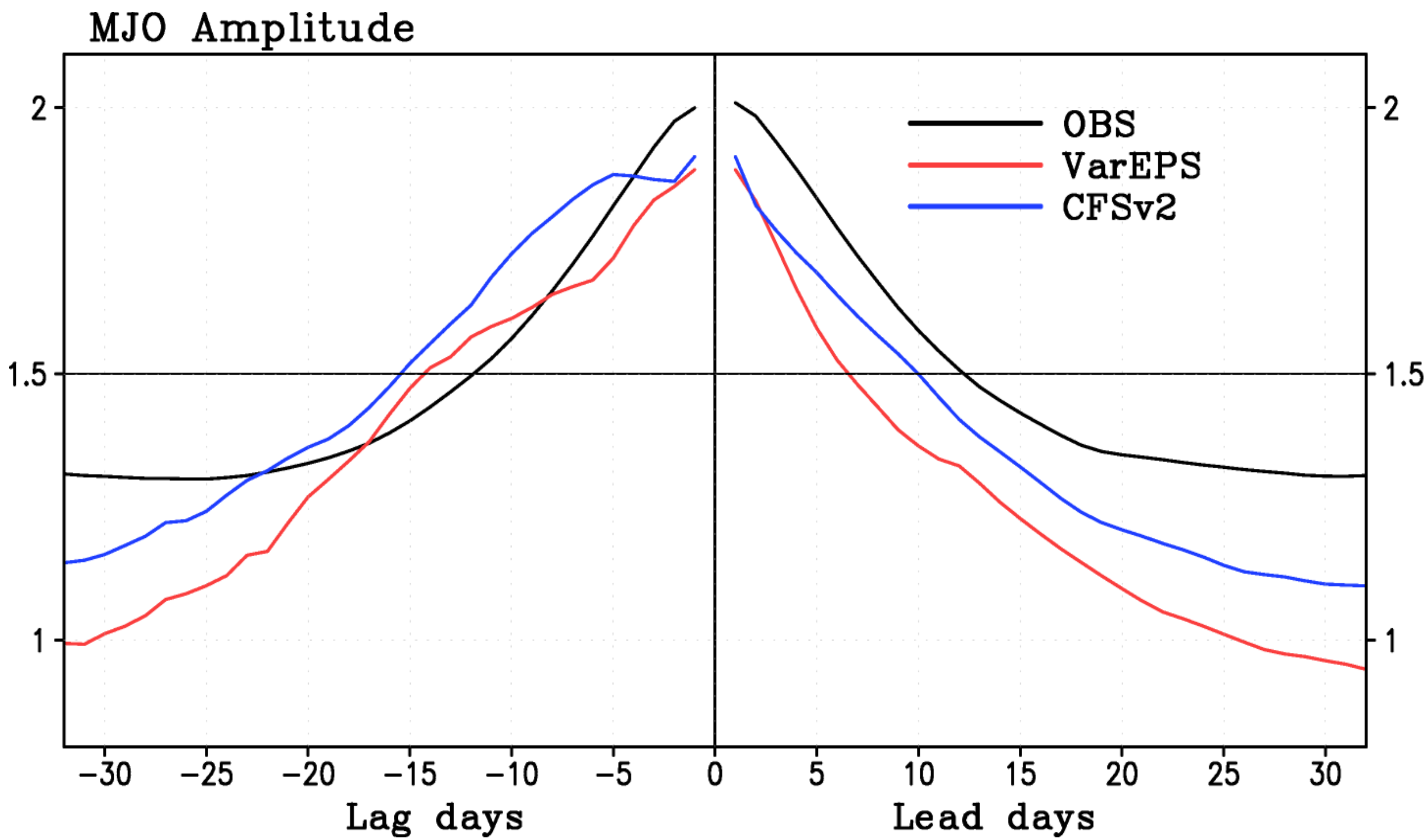
Propagating and non-propagating MJO



- Both hindcasts are able to represent the eastward propagation to some extent, but their fidelity to simulate the propagation of convective signal is much limited.
- Over the Indian Ocean, the amplitude of the OLR anomaly decreases rapidly while the amplitude of zonal wind anomaly is maintained.
- The zonal winds show slower eastward propagation speeds compared to the observed.

OLR: shading
U850: contour (purple line is the zero line)

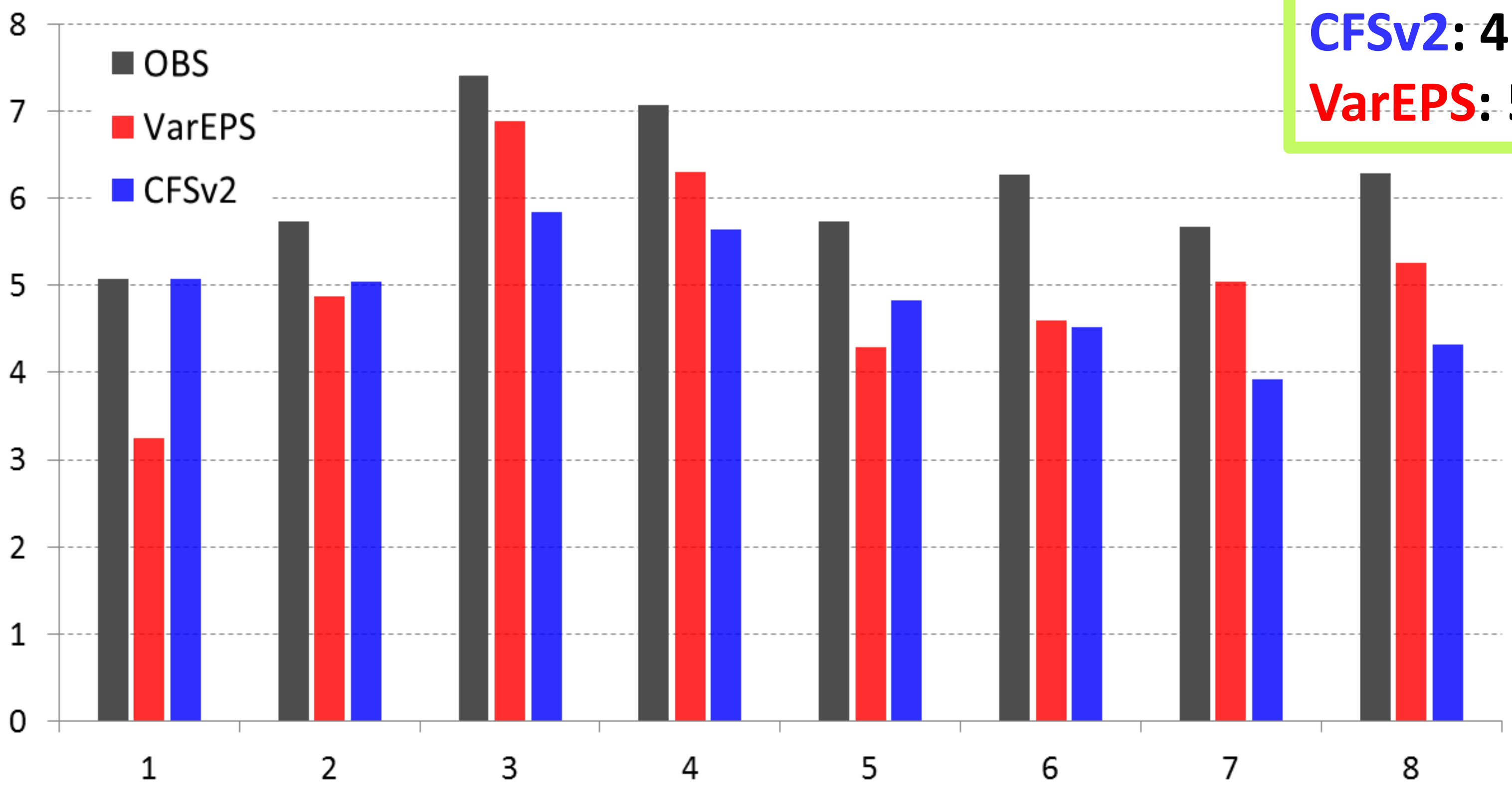
Evolution of MJO amplitude (Strong MJO case)



- MJO amplitude increases gradually as the prediction approaches a strong MJO and the amplitude decreases after reaching a strong MJO category.

MJO phase speed

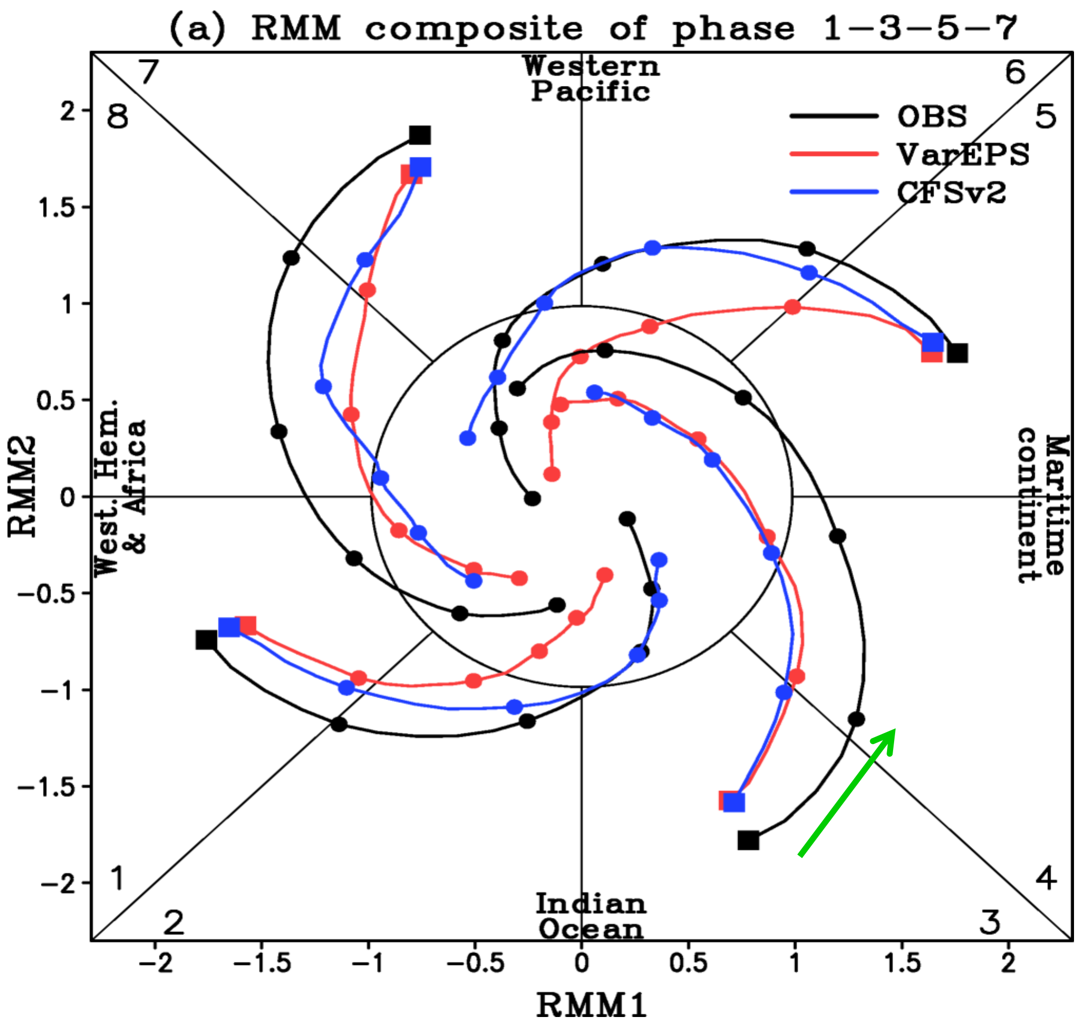
The phase speed of the initially strong MJO



OBS: 6.2 °/day
CFSv2: 4.9 °/day
VarEPS: 5.1 °/day

- The 20-days averaged phase speed (°/day)
- The predicted MJO is slower than observed

MJO composite (phase-space diagram)



- Maritime Continent barrier
- Rapid drop of MJO amplitude
- Slow propagation speed

→ Barrier for the MJO prediction

* dots: 5-days interval

Summary

- MJO is predictable (ACC>0.5) until 4 weeks forecast lead-time in VarEPS and 3 weeks in CFSv2, while the skill varies with the phase and strength of the MJO in the initial conditions.
- When forecast is targeting days with strong MJO signal, both systems are able to make useful prediction (ACC>0.5) about 30 days in advance.
- The MJO prediction skill of the two systems is dominated by the skill to predict large-scale circulation anomalies rather than that to forecast convective anomalies.
- The propagation of the MJO through the Maritime Continent is not properly represented in both systems.
- Two forecast systems possess same issue: the too-fast decrease of the MJO amplitude and the too-slow propagation speed.